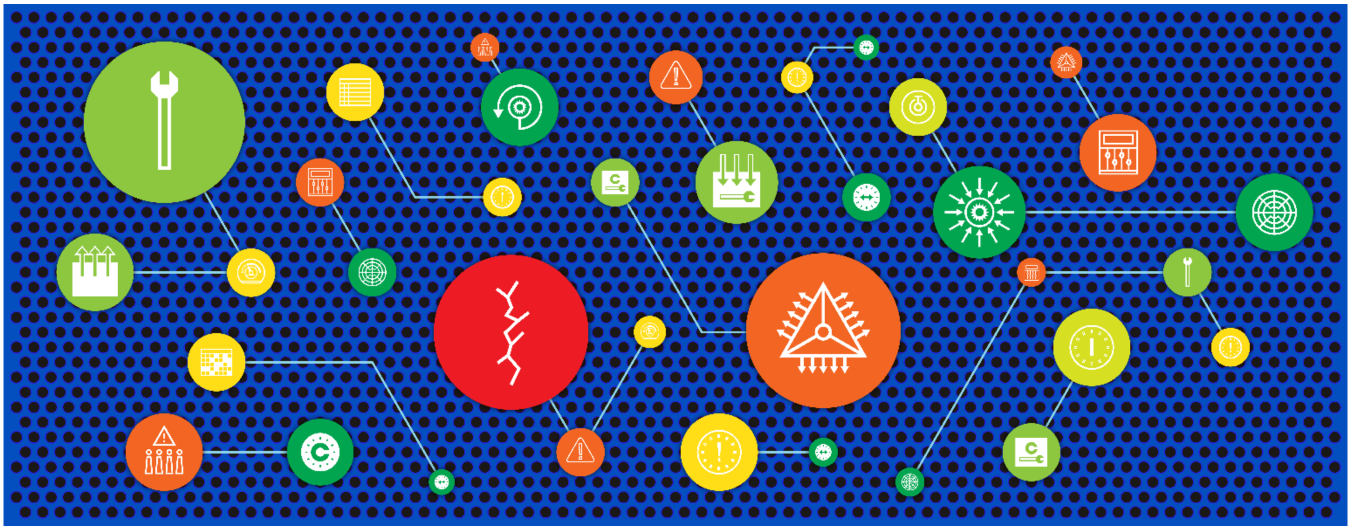
The Future of Generation: Intelligent, Integrated



EPRI Outlines Framework for Comprehensive Digital Power Plant Operations

By Brent Barker

It's early morning on what's expected to be a hot, humid day in June 2025, and operators at the Smithson Power Plant receive a dispatch request along with input from the company's fleet operations. The 12-hour wind forecast has just been revised downward, and unexpected cloud cover is moving across the region. With wind and solar output falling, Smithson's two coal units are being dispatched to meet afternoon peak demand. One, a supercritical unit, will remain in baseload operation with a modest output increase. The other—a unit refurbished five years earlier to ramp up production more quickly and to cycle production more frequently—is asked to ramp up much faster than expected to meet the air-conditioning load.

Smithson's optimization algorithms sort through thousands of tradeoffs. There are economic consequences as a result of an outage or increased maintenance costs on a 20-year old plant.

Workers with handheld computers listen and interact with the machinery, sending word to the Advanced Process Control Network to fine-tune the fuel/air mixture. Meanwhile, the Advanced Monitoring and Diagnostics Network has recognized precursors of a fault signature in the turbine thrust bearings and a potential problem in a boiler tube, likely due to creep and fatigue from the thermal stresses of daily cycling. It alerts the Advanced Operations and Maintenance (O&M) Network, which moves up a scheduled outage so that the bearings can be replaced and the boiler tube repaired.

The Optimization Central Network, which has been processing the various tradeoffs from the algorithms, suggests three feasible pathways. One: ramp up plant production slowly to 50% capacity, preventing temperature excursions that could further degrade the weakened boiler tube, but at the cost of reduced power production. Two: a steeper ramp to 75% capacity with a risk of further boiler tube degradation and still at lower production. And three: ramp up plant output swiftly to full capacity to meet the demand—but with a 16% chance of boiler tube failure. Optimization algorithms distill and portray the scenarios in simple 3-D displays for Smithson's operators, who opt for the middle course. They relay their decision to the fleet dispatch coordinators.

This is a glimpse of how integrated, intelligent generation may someday operate, driven by diverse energy resources, the growing need for flexible operations, and a digitally equipped workforce. Ultimately researchers see the likely need to integrate plants and fleets with a much more dynamic, interconnected grid.

"The mission profile of the fossil plant is changing," said Tom Alley, vice president of EPRI's Generation sector. "In the future, we may have plants called into service in the morning and shut down in the afternoon. Coal plants designed to operate 365 days per year may operate 30 days in the winter and 30 days in the summer. Workers may have to move from site to site, from one type of plant to another, requiring broader skills and greater versatility. The fossil fleet will have to shoulder much of the system flexibility."

EPRI Principal Project Manager Susan Maley offers this analogy: "Large-scale central power plants are built like semi-trailer trucks, but may be driven like a race car in a world of more flexible operations and an ever-changing dispatch landscape. They will need a set of interconnected digital networks along with actionable information to operate this way while remaining reliable and safe."

Managing Big Data

Power plant operations can shift their mission by incorporating new capabilities in digital technology. "In 10 to 20 years, operations will look like your smart phone," said Maley. "Everything you need at your fingertips, uniquely configured the way you want to meet your objectives."

Maley anticipates at least a tenfold increase in the use of advanced sensors to monitor as many plant components and processes as possible, from the coal piles to the turbine and generator to the switchyard. "These sensors will in turn create an exponential increase in real-time data—a data storm—that will have to be managed and processed," she said. Algorithms can be embedded on site servers or "clouds" that work behind the scenes to make sense of the "big data," enabling operators to focus on key decisions about operations and critical assets.

How is this possible? "Computing with large data storage and management is now cheap," she said, "You can rent storage from Amazon."

Maley and EPRI Director of Generation Fossil O&M Neva Espinoza are spearheading the "I4GEN" initiative to help power companies achieve comprehensive digital power plant operations. I4GEN—short for "developing Insight through the Integration of Information for Intelligent Generation"—offers an approach for using digital tools and techniques and deploying key technologies.

"We are challenging member companies to chart a digital path forward for power generation, taking a collaborative R&D approach," said Espinoza.

The I4GEN Framework

I4GEN focuses on three categories of enabling technologies—real-time information, distributed and adaptive intelligence, and action and response—along with six major digital/information networks (see bullets below). These networks will operate independently and in concert—similar to the interworking of the human nervous, circulatory, digestive, and other systems.

- **Sensors and actuation**: streams real-time data on all aspects of the plant—process, performance, operating conditions, equipment conditions, and actuators.
- **Data integration and information management**: processes the flood of data, converts it to actionable information, and provides the right information to the right person at the right time.
- **Advanced process control**: fine-tunes chemical, thermodynamic, mechanical, and electrical process variables, such as fuel/air mixture, combustion temperature, and steam pressure.

- **Asset monitoring and diagnostics**: tracks material and equipment degradation, identifies fault signatures, and estimates the remaining life of components.
- **Advanced O&M**: uses diagnoses of equipment degradation and faults to implement efficient O&M practices. This network initiates actions because they're needed rather than because they are common practices at set intervals.
- **Optimization**: pinpoints the least-cost path to safety, availability, and reliability.

Simulation and the Virtual Power Plant

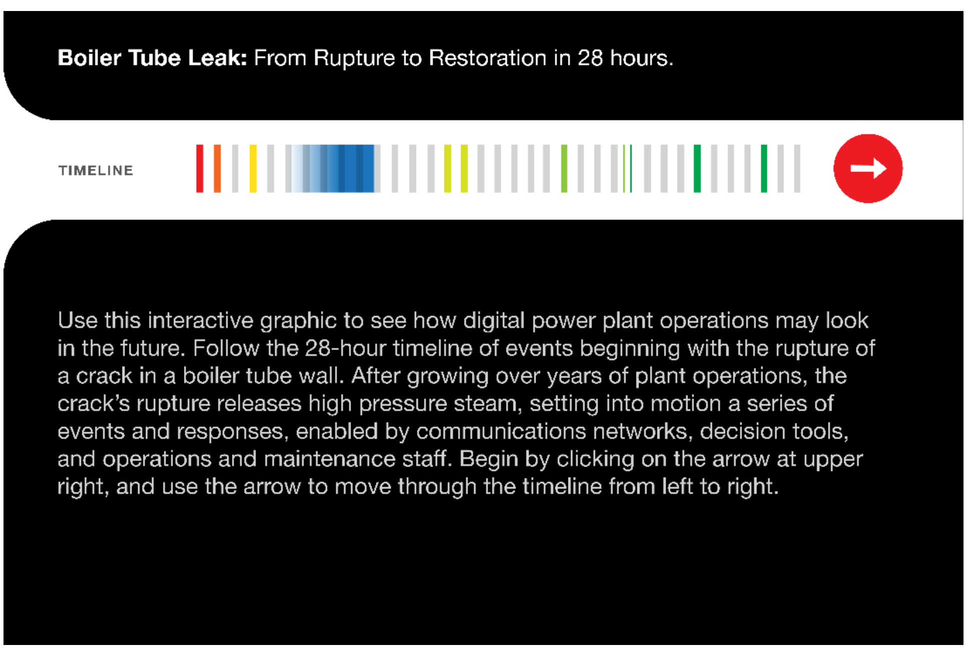
By processing a flood of real-time data, power plant simulation moves closer to reality. "Now a plant can have its own comprehensive digital, or virtual, 'twin' running by its side in near-real-time," said Maley.

The simulation doesn't control the plant directly. Instead, it integrates experience, history, and current and forecast conditions to provide the operator with a remote platform for learning, exploration, and decision making. "It's the same rationale and similar computational approaches as those for a driverless car," said Maley.

Virtual plants will be supported by algorithms that respond to changing grid conditions such as the need to ramp up power or stand by in reserve. Other algorithms will balance multiple objectives (such as enhancing safety, minimizing costs, protecting equipment, and maintaining emission levels within limits) and address shifting priorities (such as sending operators to cold-start a nearby gas turbine to meet an unanticipated surge in demand).

"If this were a car, your objective on day one might be to travel as efficiently as possible, conserving fuel," said Maley. "On day two, your objective might be to get to the same place as fast as possible."

While data transmission from plant sensors occurs in milliseconds, calculations required to optimize plant operations can take precious seconds to minutes. "Because of this time lag, optimization cannot always be automated," said Maley. "Instead, we are feeding experienced operators with distilled information, scenarios, and options to guide their decision making. Some of the toughest tradeoffs come down to financial risk/reward, and this is where operators are often better than computers. In the future, more actions could be automated so that staff have time to stay ahead of potential problems rather than react to them."



This interactive graphic depicts how digital power plant operations may look in the future.

I4GEN Next Steps

When introduced in 2015, I4GEN was well-received by EPRI's utility members. EPRI will consider advice from three member-led groups—the Operations and Maintenance Group, the Generation Council, and the Fleetwide Monitoring Interest Group—to help EPRI's efforts to refine and advance the initiative. Each utility can determine for itself to adopt various aspects and build a version aligned with its business strategy. One reasonable first step for a utility's consideration is to adopt elements with the highest return for a given plant.

"Most companies will not do a full retrofit. They will look for the most advantageous path," said Maley. "They might start with a digital backbone and then add sensing capability. That would lead them logically to invest in data management, storage, and security, followed by the adoption of advanced diagnostics and a control system upgrade. Each step paves the way for the next."

Investing in digitization will make financial sense for most new plants, but it may not result in sufficient returns for older plants, such as those retiring in the next 10 years. "The investment for digitally connecting assets is significantly less than the investment for upgrading major power plant components," said Maley. "We would like companies to consider the possibilities, devise a plan for their company or plant, and then move forward with the parts that make economic sense." She points out that companies such as Duke Energy, Southern Company, and Enel are taking similar, step-by-step approaches to digitization.

As with the smart phone, the key to successful power plant digitization is to separate the underlying complexity from user interfaces so that workers can focus on decisions and actions. "There are many talented data scientists now working on computational problems, so that we can concentrate on generating power," said Maley.

Key EPRI Technical Experts

Neva Espinoza, Susan Maley